International Journal of Science Engineering and Advance Technology, IJSEAT, Vol. 5, Issue 5 | ISSN 2321-6905 May -2017

International Journal of Science Engineering and Advance Technology

Control of a Three-Phase DC-AC Converter With an Unbalanced AC Source

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Abstract-

Three-stage dc–ac control converters experience the ill effects of energy swaying and over current issues if there should be an occurrence of the uneven air conditioning source voltage that can be caused by matrix/generator issues. Existing techniques to deal with these issues are legitimately choosing and controlling the positive-and negative-arrangement streams. In this venture, another arrangement of control techniques which use the zero grouping segments are proposed to improve the power controllability under this antagonistic condition. It is reasoned that by presenting legitimate zero-arrangement current controls and comparing circuit designs, the power converter can empower more adaptable control targets, accomplishing better exhibitions in the conveyed control and the heap current when experiencing the unequal voltage. fuzzy controller is utilized for the better smoothening of yield wave shapes. Recreation results are exhibited to check the attainability of the proposed approach in MATLAB/SIMULINK condition.

Index Terms - Control technique, dc–ac converter, adaptation to internal failure, uneven air conditioning source.

I.INTRODUCTION

In numerous vital applications for power hardware, for example, sustainable power source era, engine drives, control quality, and small scale network, and so on., the three-stage dc–ac converters are basic segments as the power stream interface of dc and air conditioning electrical frameworks. As appeared in Fig. 1, a dc–ac voltage source converter with a comparing channel is normally used to change over the vitality between the dc transport and the three-stage air conditioning sources, which could be the power lattice, era units, or the electric machines relying upon the applications and controls. Since the power gadgets are getting so generally utilized and getting to be plainly fundamental in the vitality transformation innovation, the disappointments or closing down of these spine dc–ac converters may bring about significant issues and cost. It is turning into a need in numerous applications that the power converters ought to be solid to withstand a few issues or unsettling influences keeping in mind the end goal to guarantee certain accessibility of the vitality supply. A decent illustration can be found in the wind control application, where both the aggregate introduced limit and individual limit of the power transformation framework are moderately high.

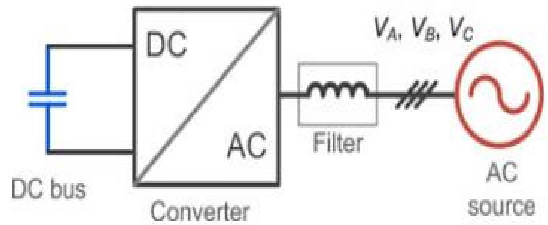


Fig. 1.Typical dc–ac power converter application.

The sudden disengagement of the power converter may cause noteworthy effects on the matrix solidness and furthermore on the high cost for support/repair. Accordingly, transmission framework administrators (TSOs) in various nations have been issuing strict necessities for the wind turbine conduct under lattice issues. As appeared in Fig. 2, the wind control converter ought to be associated (or even continue producing power) under different lattice voltage plunges for certain time as per the plunge seriousness, and in some uncritical conditions (e.g.,90% voltage plunge), the power converter may require long-term operation.

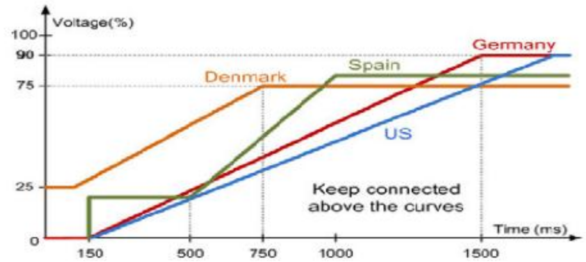


Fig. 2. Grid codes of wind turbines under the grid voltage dip by different countries.

At the point when the air conditioner source appeared in Fig. 1 winds up noticeably misshaped under issues or unsettling influences, the lopsided air conditioning voltages have been turned out to be one of the best difficulties for the control of the dc–ac converter so as to keep them ordinarily working and associated with the air conditioner source. Unique control techniques which can direct both the positive-and negative arrangement streams have been acquainted with handle these issues. Nonetheless, the subsequent exhibitions by these control techniques appear to be as yet not agreeable: either mutilated load streams or power motions will be displayed, and in this way the air conditioner source as well as the power converter will be additionally focused on going with the exorbitant outline contemplations.

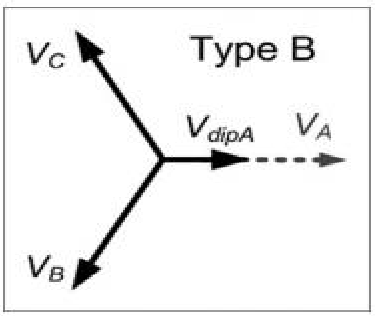


Fig. 3.Phasor diagram definitions for the voltage dips in the ac source of Fig. 1. *VA* , *VB* , and *VC* means the voltage of three phases in the ac source.

This venture focuses to comprehend and enhance the power control breaking points of a common three-stage dc–ac converter framework under the uneven air conditioning source. Another arrangement of control methodologies which uses the zero-grouping parts are then proposed to improve the power control capacity under this antagonistic condition. Other than the network coordination, the proposed control strategies can possibly be connected under different applications like the engine/generator associations or small scale matrices, where the unequal air conditioning voltage is probably going to be exhibited; along these lines, the essential guideline and possibility are primarily engaged.

II.MODELING OF PROPOSED THEORY

LIMITS OF A TYPICAL THREE-WIRE CONVERTER SYSTEM

Keeping in mind the end goal to dissect the controllability and the execution of the power hardware converter under an unfavorable air conditioning source, as each unequal air conditioning voltage is first characterized as a contextual analysis in this venture. As appeared in Fig. 3, the phasor outline of the three stage mutilated air conditioning voltage are shown, it is expected that the sort B blame occurs with the huge voltage plunge on stage An of the air conditioner source. Additionally, there are numerous different sorts of voltage flaws which have been characterized as sort A–F. As indicated by [2] and [19], any twisted three-stage voltage can be communicated by the total of segments in the positive grouping, negative arrangement, and zero succession. For effortlessness of investigation, just the parts with the central recurrence are considered in this venture, be that as it may, it is additionally conceivable to extend the examination to higher request sounds. The misshaped three-stage air conditioning source voltage in Fig. 3 can be spoken to by

$$\mathbf{V_S} = \mathbf{V}^+ + \mathbf{V}^- + \mathbf{V}^0 = \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = V^+ \begin{bmatrix} \sin(\omega t + \varphi^+) \\ \sin(\omega t - 120^\circ + \varphi^+) \\ \sin(\omega t + 120^\circ + \varphi^+) \end{bmatrix} + V^- \begin{bmatrix} \sin(\omega t + \varphi^-) \\ \sin(\omega t + 120^\circ + \varphi^-) \\ \sin(\omega t - 120^\circ + \varphi^-) \end{bmatrix} + V^0 \begin{bmatrix} \sin(\omega t + \varphi^0) \\ \sin(\omega t + \varphi^0) \\ \sin(\omega t + \varphi^0) \end{bmatrix} \quad (1)$$

Where $V+$,$V-$, and $V0$ are the voltage amplitude in the positive, negative, and zero sequence, respectively. And $\phi+$, $\phi-$, and$\phi0$ represent the initial phase angles in the positive sequence, negative sequence, and zero sequence, respectively. The predefined voltage dip as indicated in Fig. 3 should contain voltage components in all the three sequences [2], [11]

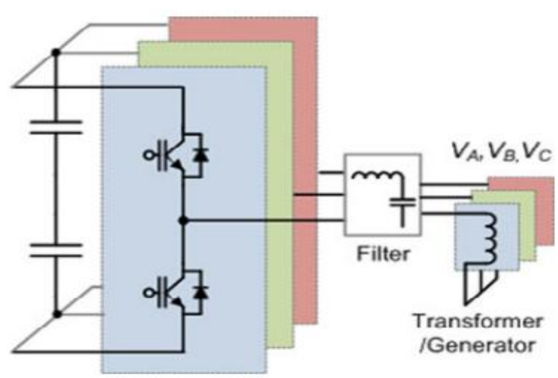


Fig. 4. Typical three-phase three-wire 2L-voltage source converter

TABLE I
CONVERTER PARAMETERS FOR THE CASE STUDY

Rated output active power P_o	10 MW
DC bus voltage V_{dc}	5.6 kV DC
*Rated primary side voltage V_p	3.3 kV rms
Rated line-to-line grid voltage V_g	20 kV rms
Rated load current I_{load}	1.75 kA rms
Carrier frequency f_c	750 Hz
Filter inductance L_f	1.1 mH (0.25 p.u.)

*Line-to-line voltage in the primary windings of transformer.

A typically used three-phase three-wire two-level voltage source dc–ac converter is chosen and basically designed, as shown in Fig. 4 and Table I, where the converter configuration and the parameters are indicated, respectively. It is noted that the three-phase ac source is represented here by three winding switch a common neutral point, which can be the windings of an electric machine or a transformer Because there are only three wires and a common neutral point in the windings of the ac source, the currents flowing in the three phases do not contain zero-sequence components. As a result, the three-phase load current controlled by the converter can be written as

$$\mathbf{I_C} = \mathbf{I}^{+} + \mathbf{I}^{-}. \qquad (2)$$

With the voltage of the ac source in (1) and the current controlled by the converter in (2), the instantaneous real power p and the imaginary power q in $\alpha\beta$ coordinate, as well as the realpower$p0$ in the zero coordinate can be calculated as

$$\begin{bmatrix} p \\ q \\ p_0 \end{bmatrix} = \begin{bmatrix} v_\alpha \cdot i_\alpha + v_\beta \cdot i_\beta \\ v_\alpha \cdot i_\beta - v_\alpha \cdot i_\beta \\ v_0 \cdot 0 \end{bmatrix} = \begin{bmatrix} \overline{P} + P_{c2} \cdot \cos(2\omega t) + P_{s2} \cdot \sin(2\omega t) \\ \overline{Q} + Q_{c2} \cdot \cos(2\omega t) + Q_{s2} \cdot \sin(2\omega t) \\ 0 \end{bmatrix} \qquad (3)$$

Then, the instantaneous three-phase real power $p3\Phi$ and the imaginary power $q3\Phi$ of the ac source/converter can be written as

$$\begin{bmatrix} p_{3\phi} \\ q_{3\phi} \end{bmatrix} = \begin{bmatrix} p + p_0 \\ q \end{bmatrix} = \begin{bmatrix} \overline{P} \\ \overline{Q} \end{bmatrix} + \begin{bmatrix} P_{c2} \\ Q_{c2} \end{bmatrix} \cos(2\omega t) + \begin{bmatrix} P_{s2} \\ Q_{s2} \end{bmatrix} \sin(2\omega t) \qquad (4)$$

Where P and Q are the average parts of the real and imaginary power, $Pc2$,$Ps2$ and $Qc2$,$Qs2$ are the oscillation parts, which can be calculated as

$$\overline{P} = \frac{3}{2}(v_d^+ \cdot i_d^+ + v_q^+ \cdot i_q^+ + v_d^- \cdot i_d^- + v_q^- \cdot i_q^-)$$

$$P_{c2} = \frac{3}{2}(v_d^- \cdot i_d^+ + v_q^- \cdot i_q^+ + v_d^+ \cdot i_d^- + v_q^+ \cdot i_q^-)$$

$$P_{s2} = \frac{3}{2}(v_q^- \cdot i_d^+ - v_d^- \cdot i_q^+ - v_q^+ \cdot i_d^- + v_d^+ \cdot i_q^-)$$

(5)

$$\overline{Q} = \frac{3}{2}(v_q^+ \cdot i_d^+ - v_d^+ \cdot i_q^+ + v_q^- \cdot i_d^- - v_d^- \cdot i_q^-)$$

$$Q_{c2} = \frac{3}{2}(v_q^- \cdot i_d^+ - v_d^- \cdot i_q^+ + v_q^+ \cdot i_d^- - v_d^+ \cdot i_q^-)$$

$$Q_{s2} = \frac{3}{2}(-v_d^- \cdot i_d^+ - v_q^- \cdot i_q^+ + v_d^+ \cdot i_d^- + v_q^+ \cdot i_q^-)$$

(6)

where a positive dq synchronous reference frame and a negative dq synchronous reference frame are applied, respectively, to the positive- and negative-sequence voltage/current. Each of the components on the corresponding positive- and negative-dq axis can be written as

$$\begin{aligned} v_d^+ &= V^+ \cos(\varphi^+) \\ v_q^+ &= V^+ \sin(\varphi^+) \\ v_d^- &= V^- \cos(\varphi^-) \\ v_q^- &= -V^- \sin(\varphi^-) \end{aligned} \qquad (7)$$

$$
\begin{aligned}
i_d^+ &= I^+ \cos(\delta^+) \\
i_q^+ &= I^+ \sin(\delta^+) \\
i_d^- &= I^- \cos(\delta^-) \\
i_q^- &= -I^- \sin(\delta^-).
\end{aligned} \tag{8}
$$

Then, (5) and (6) can be formulated as a matrix relation as

$$
\begin{bmatrix} \overline{P} \\ \overline{Q} \\ P_{s2} \\ P_{c2} \end{bmatrix} = \frac{3}{2} \begin{bmatrix} v_d^+ & v_q^+ & v_d^- & v_q^- \\ v_q^+ & -v_d^+ & v_q^- & -v_d^- \\ v_q^- & -v_d^- & -v_q^+ & v_d^+ \\ v_d^- & v_q^- & v_d^+ & v_q^+ \end{bmatrix} \tag{9}
$$

It can be seen from (9) that if the ac source voltage is decided, then the converter has four controllable freedoms ($i+d$,$i+q$, $i-d$,and $i-q$) to regulate the current flowing in the ac source. That also means: four control targets/functions can be established. Normally, the three-phase average active and reactive powers delivered by the converter are two basic requirements for a given application, then, two control targets have to be first settled as

$$
\begin{aligned}
\overline{P_{3\phi}} &= \overline{P} = P_{\text{ref}} \\
\overline{Q_{3\phi}} &= \overline{Q} = Q_{\text{ref}}.
\end{aligned} \tag{10}
$$

It is noted that different applications may have different requirements for the control of the average power, e.g., in the power production application, the active power reference Pref injected to the grid is normally set as positive, meanwhile the large amount of the reactive power Qref may be needed in order to help to support the grid voltage [12], [13]. As for the electric machine application, the Pref is set as negative for the generative mode and positive for the motor mode, there may be no or just a few reactive power Qref requirements for magnetizing of the electric machine. While in most power quality applications, e.g. ,STACOM, Pref is normally set to be very small to provide the converter loss, and a large amount of Qref is normally required.

Consequently, for the three-phase three-wire converter system, there are only two more current control freedoms left to achieve another two control targets besides (10). These two adding control targets may be utilized to further improve the performances of the converter under the unbalanced ac source, which have been generally investigated in [2] and [16]–[18].However, this project focuses more on the evaluation of control limits and the control possibilities under the whole voltage dipping range. In the following, two of the most mentioned control methods achieved by three-wire converter structure are investigated under the unbalanced ac source.

A. *Elimination of the Negative-Sequence Current*

In most of the grid integration applications, there are strict grid codes to regulate the behavior of the grid connected converters. The negative-sequence current which always results in the unbalanced load current may be unacceptable from the point view of a TSO [13]. Therefore, extra two control targets which aim to eliminate the negative-sequence current can be added as

$$
\begin{aligned}
i_d^- &= 0 \\
i_q^- &= 0.
\end{aligned} \tag{11}
$$

Translating the control targets in (10) and (11), all the controllable current components can be calculated as

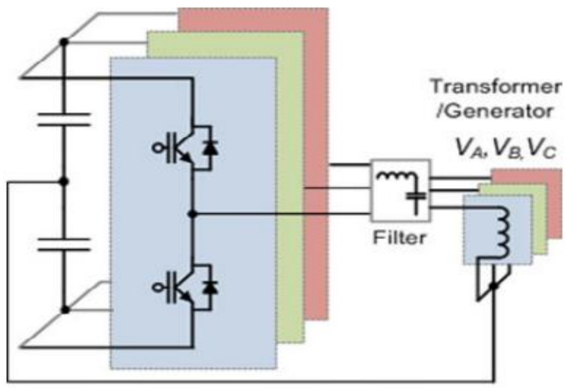
$$
\begin{aligned}
i_d^+ &= \frac{2}{3} \cdot \frac{v_d^+ \cdot P_{\text{ref}} + v_q^+ \cdot Q_{\text{ref}}}{(v_d^+)^2 - (v_d^-)^2} \\
i_q^+ &= \frac{2}{3} \cdot \frac{P_{\text{ref}}}{v_d^+} - \frac{v_d^+}{v_q^+} \cdot i_d^+
\end{aligned} \tag{12}
$$

$$
\begin{aligned}
i_d^- &= 0 \\
i_q^- &= 0.
\end{aligned} \tag{13}
$$

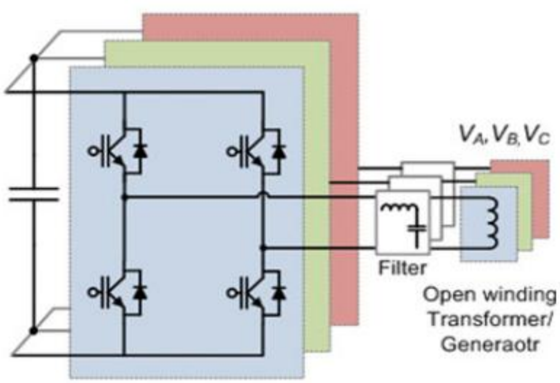
III.CONVERTER SYSTEM WITH THE ZERO-SEQUENCECURRENT PATH

As can be concluded, in the typical three-phase three-wire converter structure, four control freedoms for the load current seem to be not enough to achieve satisfactory performances under the unbalanced ac source. (No matter what combinations of control targets are used, either significant power oscillation or overloaded/distorted current will be presented.) Therefore, more current control freedoms are needed in order to improve the control performance under the unbalanced ac source conditions.

Another series of the converter structure are shown as indicated as the four-wire system in Fig. 9(a) and the six-wire system in Fig. 5(b). Compared to the three-wire converter structure, these types of converters introduce the zero-sequence current path [24]–[26], which may enable extra current control freedoms to achieve better power control performances. It is noted that in the grid-connected application, the zero-sequence current is not injected into the grid but trapped in the typically used *d-Y* transformer.



(a)



(b)

Fig. 5.Converter structure with the zero-sequence current path. (a) Four-wire system. (b) Six-wire system.

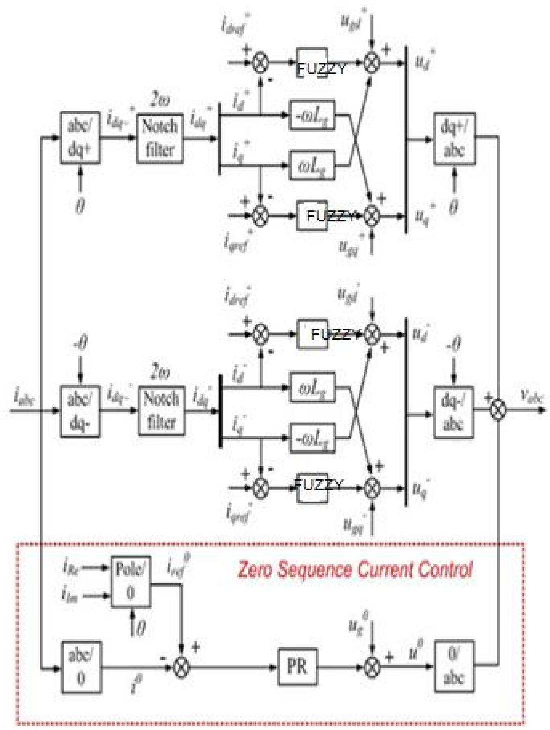


Fig. 6. Control structure for the converter system with the zero-sequence current.

A potential control structure is proposed in Fig. 10, in which an extra control loop is introduced to enable the controllability of the zero-sequence current. After introducing the regulated zero-sequence current, the three-phase current generated by the converter can be written as [27]–[29]

$$\mathbf{I_C} = \mathbf{I}^{+} + \mathbf{I}^{-} + \mathbf{I}^{0}. \quad (14)$$

By operating the voltage of the ac source (1) and the current controlled by the power converter (14), the instantaneous generated real power *p*, the imaginary power *q* in the *αβ* coordinate, and the real power *p*0 in the zero coordinate can be calculated as

$$\begin{bmatrix} p \\ q \\ p_0 \end{bmatrix} = \begin{bmatrix} v_\alpha \cdot i_\alpha + v_\beta \cdot i_\beta \\ v_\alpha \cdot i_\beta - v_\alpha \cdot i_\beta \\ v_0 \cdot i_0 \end{bmatrix}$$
$$= \begin{bmatrix} \overline{P} + P_{c2} \cdot \cos(2\omega t) + P_{s2} \cdot \sin(2\omega t) \\ \overline{Q} + Q_{c2} \cdot \cos(2\omega t) + Q_{s2} \cdot \sin(2\omega t) \\ \overline{P_0} + P_{0c2} \cdot \cos(2\omega t) + P_{0s2} \cdot \sin(2\omega t \end{bmatrix}$$

(15)

Then, the instantaneous three-phase real power $p3\Phi$ and the imaginary power $q3\Phi$ of the converter can be written as

$$\begin{bmatrix} p_{3\phi} \\ q_{3\phi} \end{bmatrix} = \begin{bmatrix} p + p_0 \\ q \end{bmatrix} = \begin{bmatrix} \overline{P} + \overline{P_0} \\ \overline{Q} \end{bmatrix}$$
$$+ \begin{bmatrix} P_{c2} + P_{0c2} \\ Q_{c2} \end{bmatrix} \cos(2\omega t) + \begin{bmatrix} P_{s2} + P_{0s2} \\ Q_{s2} \end{bmatrix} \sin(2\omega$$

(16)

It is noted that the voltage and the current in zero sequence only contribute to the real power $p3\Phi$ of the converter. Each part of (16) can be calculated as

$$\overline{P} = \frac{3}{2}(v_d^+ \cdot i_d^+ + v_q^+ \cdot i_q^+ + v_d^- \cdot i_d^- + v_q^- \cdot i_q^-)$$
$$P_{c2} = \frac{3}{2}(v_d^- \cdot i_d^+ + v_q^- \cdot i_q^+ + v_d^+ \cdot i_d^- + v_q^+ \cdot i_q^-)$$
$$P_{s2} = \frac{3}{2}(v_q^- \cdot i_d^+ - v_d^- \cdot i_q^+ - v_q^+ \cdot i_d^- + v_d^+ \cdot i_q^-)$$

(17)

$$\overline{Q} = \frac{3}{2}(v_q^+ \cdot i_d^+ - v_d^+ \cdot i_q^+ + v_q^- \cdot i_d^- - v_d^- \cdot i_q^-)$$
$$Q_{c2} = \frac{3}{2}(v_q^- \cdot i_d^+ - v_d^- \cdot i_q^+ + v_q^+ \cdot i_d^- - v_d^+ \cdot i_q^-)$$
$$Q_{s2} = \frac{3}{2}(-v_d^- \cdot i_d^+ - v_q^- \cdot i_q^+ + v_d^+ \cdot i_d^- + v_q^+ \cdot i_q^-)$$

(18)

$$\overline{P_0} = \frac{3}{2}(v_{\mathrm{Re}}^0 \cdot i_{\mathrm{Re}}^0 + v_{\mathrm{Im}}^0 \cdot i_{\mathrm{Im}}^0)$$
$$P_{0c2} = \frac{3}{2}(v_{\mathrm{Re}}^0 \cdot i_{\mathrm{Re}}^0 - v_{\mathrm{Im}}^0 \cdot i_{\mathrm{Im}}^0)$$
$$P_{0s2} = \frac{3}{2}(-v_{\mathrm{Im}}^0 \cdot i_{\mathrm{Re}}^0 - v_{\mathrm{Re}}^0 \cdot i_{\mathrm{Im}}^0).$$

(19)

Then, the relationship can be formulated to a matrix equation as

$$\begin{bmatrix} \overline{P} + \overline{P_0} \\ P_{c2} + P_{0c2} \\ P_{s2} + P_{0s2} \\ \overline{Q} \\ Q_{c2} \\ Q_{s2} \end{bmatrix}$$
$$= \frac{3}{2} \begin{bmatrix} v_d^+ & v_q^+ & v_d^- & v_q^- & v_{\mathrm{Re}}^0 & v_{\mathrm{Im}}^0 \\ v_d^- & v_q^- & v_d^+ & v_q^+ & v_{\mathrm{Re}}^0 & -v_{\mathrm{Im}}^0 \\ v_q^- & -v_d^- & -v_q^+ & v_d^+ & -v_{\mathrm{Im}}^0 & -v_{\mathrm{Re}}^0 \\ v_q^+ & -v_d^+ & v_q^- & -v_d^- & 0 & 0 \\ v_q^- & -v_d^- & v_q^+ & -v_d^+ & 0 & 0 \\ -v_d^- & -v_q^- & v_d^+ & v_q^+ & 0 & 0 \end{bmatrix} \begin{bmatrix} i_d^+ \\ i_q^+ \\ i_d^- \\ i_q^- \\ i_{\mathrm{Re}}^0 \\ i_{\mathrm{Im}}^0 \end{bmatrix}$$

(20)

It is noted that unlike the traditional approach in which the zero sequence components are normally minimized, the zero sequence voltage and the current here look like single-phase AC components running at the same fundamental frequency. As a result, the zero-sequence voltage/current can be represented by vectors in a synchronous reference frame in the zero sequence as

$$\mathbf{V_0} = v_{\mathrm{Re}}^0 + v_{\mathrm{Im}}^0 j$$
$$\mathbf{I_0} = i_{\mathrm{Re}}^0 + i_{\mathrm{Im}}^0 j \qquad (21)$$

where the real part and imaginary part can be represented as follows:

$$
\begin{aligned}
v_{\mathrm{Re}}^{0} &= V^{0}\cos(\varphi^{0}) \\
v_{\mathrm{Im}}^{0} &= V^{0}\sin(\varphi^{0}) \\
i_{\mathrm{Re}}^{0} &= I^{0}\cos(\delta^{0}) \\
i_{\mathrm{Im}}^{0} &= I^{0}\sin(\delta^{0}).
\end{aligned} \tag{22}
$$

It can be seen from (22) that if the three-phase ac source voltage is decided, then the converter has six controllable freedoms ($i^+_d, i^+_q, i^-_d, i^-_q, i^0_{\mathrm{Re}}$, and i^0_{Im}) to regulate the current flowing in the ac source. That means: six control targets/functions can be established by the converter having the zero-sequence current path. Similarly, the three-phase average active and reactive power delivered by the converter are two basic requirements for a given application, then, two control functions need to be first settled as

$$
\begin{aligned}
\overline{P_{3\phi}} &= \overline{P} + \overline{P_0} = P_{\mathrm{ref}} \\
\overline{Q_{3\phi}} &= \overline{Q} = Q_{\mathrm{ref}}.
\end{aligned} \tag{23}
$$

So, for the converter system with the zero-sequence current path, there are four control freedoms left to achieve two more control targets than the traditional three-wire system, this also means extended controllability and better performance under the unbalanced ac source.

A. Elimination of Both the Active and Reactive Power Oscillation.

Because of more current control freedoms, the power converter with the zero-sequence current path can not only eliminate the oscillation in the active power, but also cancel the oscillation in the reactive power at the same time. This control targets can be written as

$$
\begin{aligned}
P_{3\phi c2} &= P_{c2} + P_{0c2} = 0 \\
P_{3\phi s2} &= P_{s2} + P_{0s2} = 0
\end{aligned} \tag{24}
$$

$$
\begin{aligned}
Q_{c2} &= 0 \\
Q_{s2} &= 0.
\end{aligned} \tag{25}
$$

The power oscillation caused by the zero-sequence current P_{0c2} and P_{0s2} are used to compensate the power oscillation caused by the positive- and negative-sequence currents P_{c2} and P_{s2}. When combing (26), (30), and (31), each of the current components controlled by converter can be calculated as

$$
\begin{bmatrix} i_d^+ \\ i_q^+ \\ i_d^- \\ i_q^- \\ i_{\mathrm{Re}}^0 \\ i_{\mathrm{Im}}^0 \end{bmatrix}
= \frac{2}{3}
\begin{bmatrix}
v_d^+ & v_q^+ & v_d^- & v_q^- & v_{\mathrm{Re}}^0 & v_{\mathrm{Im}}^0 \\
v_d^- & v_q^- & v_d^+ & v_q^+ & v_{\mathrm{Re}}^0 & -v_{\mathrm{Im}}^0 \\
v_q^- & -v_d^- & -v_q^+ & v_d^+ & -v_{\mathrm{Im}}^0 & -v_{\mathrm{Re}}^0 \\
v_q^+ & -v_d^+ & v_q^- & -v_d^- & 0 & 0 \\
v_q^- & -v_d^- & v_q^+ & -v_d^+ & 0 & 0 \\
-v_d^- & -v_q^- & v_d^+ & v_q^+ & 0 & 0
\end{bmatrix}^{-1}
\begin{bmatrix} P_{\mathrm{ref}} \\ 0 \\ 0 \\ Q_{\mathrm{ref}} \\ 0 \\ 0 \end{bmatrix}. \tag{26}
$$

In order to facilitate the analytical solution, assuming that the *d*-axis or the real axis in the synchronous reference frame is allied with the voltage vectors in each of the sequence (positive, negative, and zero), then all of the controllable current components with the zero-sequence current path can be solved by

$$
\begin{aligned}
i_d^+ &\approx \frac{2}{3} \cdot \frac{P_{\mathrm{ref}}}{(v_d^+ - v_d^-)\cdot(1 - v_d^-/v_d^+)} \\
i_q^+ &\approx \frac{2}{3} \cdot \frac{Q_{\mathrm{ref}}}{-v_d^+ + (v_d^-)^2/v_d^+}
\end{aligned} \tag{33}
$$

$$
\begin{aligned}
i_d^- &\approx \frac{v_d^-}{v_d^+} \cdot i_d^+ \\
i_q^- &\approx -\frac{v_d^-}{v_d^+} \cdot i_q^+
\end{aligned} \tag{27}
$$

IV.FUZZY LOGIC CONTROL

FLC controlled by the arrangement of etymological principles. The scientific demonstrating is not required in fuzzy controller because of the transformation of numerical variable into semantic factors. FLC comprises of three section: a. Fuzzification, b. Impedance motor, c. Defuzzification. The fuzzy controller is described as; For each info and yield there are seven fuzzy sets. For straightforwardness an enrollment capacities is Triangular. Fuzzification is utilizing constant universe of talk. Suggestion is utilizing Mamdani's "min" administrator. Defuzzification is utilizing the "stature" technique. FLC square chart as appeared in figure 2.

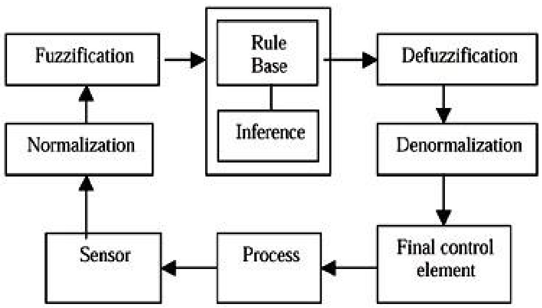


Fig. 7. Fuzzy Logic Controller

a. Fuzzification

Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB(Negative Big), NM(Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small),PM(Positive Medium) and PB (Positive Big). The partition of fuzzy subsets and the shape of membership function adapt the shape up to appropriate system. Input error E(k) and change in error CE(k) of values which is normalized by an input scaling factor as shown in table 1.

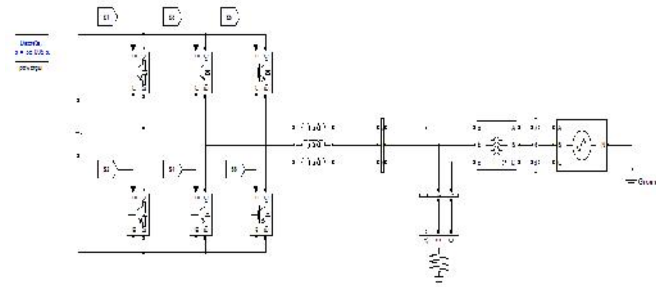
ε / $\Delta\varepsilon$	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

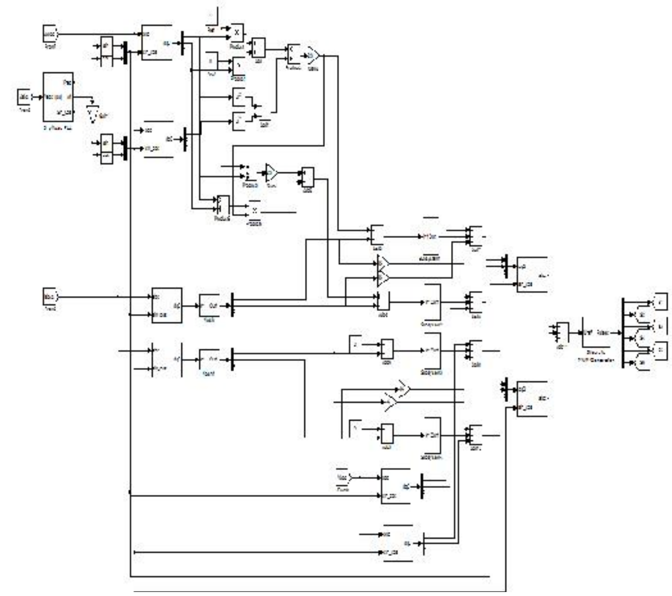
Table1:Fuzzy Rules

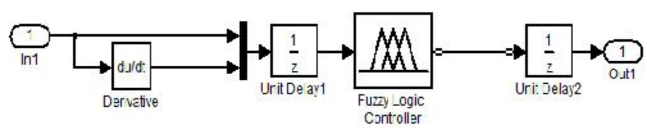
In this system the input scaling factor is between -1 and +1 has design. The triangular shape of the membership function of this arrangement presumes that for any particular input there is only one dominant fuzzy subset . The input error E(k) and change in error C(k) for the FLC is given as

SIMULINK MODELLING AND RESULTS

5.1 Simulink modeling diagrams:







5.2 Block diagrams of fuzzy logic controller.

Simulation results of fuzzy logic controller:

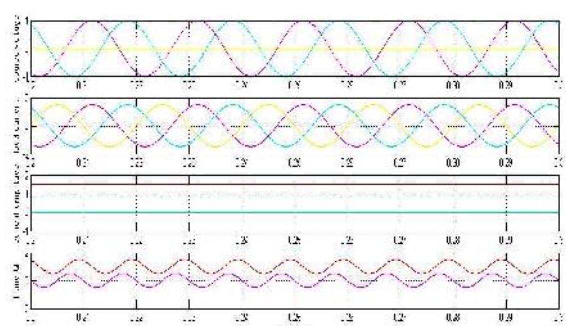


Fig.5.3. Simulation of the converter with no negative-sequence current control (three-phase three-wire converter, Pref = 1 p.u., Qref = 0 p.u.,$Id-$ = 0 p.u., $Iq-$

=0 p.u., VA = 0 p.u., $I+$, $I-$, and $I0$ means the amplitude of the current in the positive negative, and zero sequences, respectively.

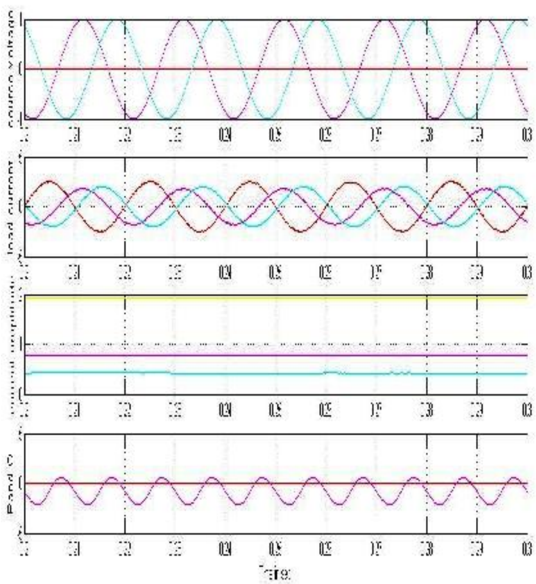


Fig.5.4 Simulation of the converter control with no active power oscillation (three-phase three-wire converter, Pref = 1 p.u., Qref = 0 p.u., $Ps2$ = 0 p.u., Pc 2 = 0 p.u., VA = 0 p.u. $I+$, $I-$, and $I0$ means the amplitude of the current in the positive, negative, and zero sequences, respectively.

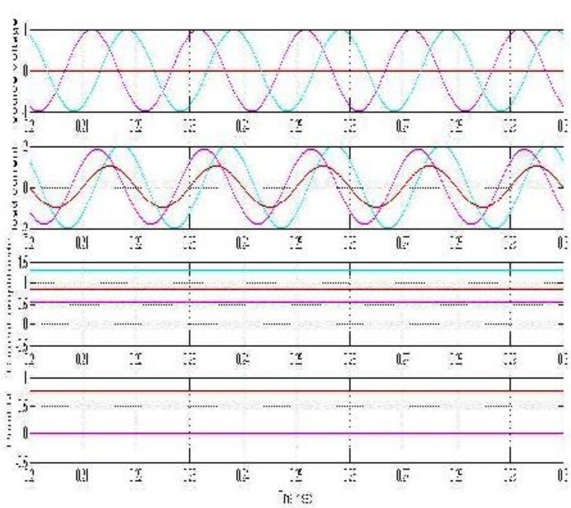


Fig.5.5 Simulation of converter control with no active and reactive power oscillation (three-phase converter with the zero-sequence path, Pref = 1 p.u., Qref = 0 p.u., $Ps2$ = 0 p.u., Pc 2 = 0 p.u., $Qs2$ = 0 p.u., $Qc2$ = 0 p.u., VA = 0 p.u.).

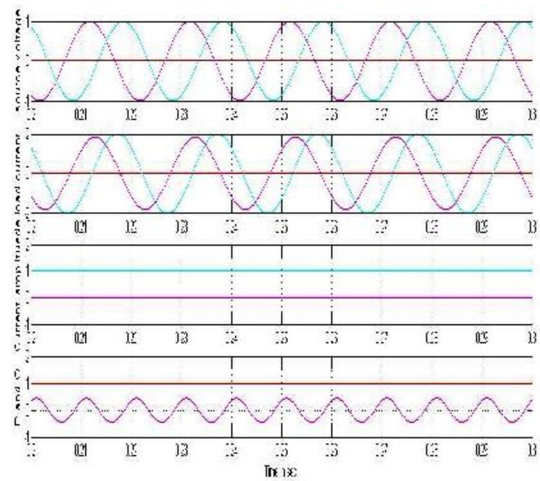


Fig.5.6 Simulation of converter control with no active power oscillation andno negative sequence (three-phase converter with the zero-sequence current path,Pref= 1 p.u., Qref = 0 p.u., $Ps2$ = 0 p.u., Pc 2 = 0 p.u., $id-$ = 0 p.u., $iq-$ = 0 p.u., VA= 0 p.u. $I+$, I-, and $I0$ means the amplitude of the current in the positive, negative, and zero sequences, respectively).

CONCLUSION

In a typical three-phase three-wire converter structure, there are four current control freedoms, and it may be not enough to achieve satisfactory performances under the unbalanced ac source, because either significantly the oscillated power or the overloaded current will be presented. In the three-phase converter structure with the zero sequence current path, there are six current control freedoms. The extra two control freedoms coming from the zero sequence current can be utilized to extend the controllability of the converter and improve the control performance under the unbalanced ac source.

By the proposed control strategies, it is possible to totally cancel the oscillation in both the active and the reactive power, reduced the oscillation amplitude in the reactive power. Meanwhile, the current amplitude of the faulty phase is significantly relieved without further increasing the current amplitude in the normal phases. The advantage and features of the proposed controls can be still maintained under various conditions when delivering the reactive power. The analysis and proposed control methods are well agreed by simulation validations. Fuzzy controller is used for the better smoothening of output wave forms. Simulation results are presented to verify the feasibility of the proposed approach in MATLAB /SIMULINK environment.

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